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THE FLEXIBILITY OF WEATHERED RUBBER-COATED FABRICS.(U)

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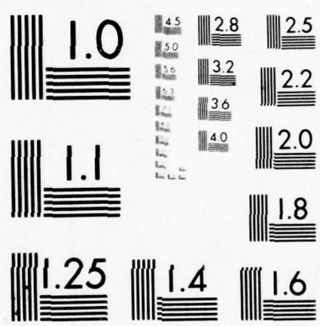

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THE FLEXIBILITY OF WEATHERED RUBBER-COATED FABRICS

by

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SUMMARY

The effects of 1 year of weathering on the flexibility of rubber-coated fabrics was studied in 208 combinations of base fabric, rubber type, time, site and stress level. Throughout, coated nylon fabrics were thicker, heavier and less flexible than coated cotton fabrics, the base fabrics being similar in mass per unit area. Fabrics coated with polyurethane or chlorosulphonated polyethylene tended to be thicker than those with natural or neoprene rubbers, whilst chlorosulphonated polyethylene coated fabrics were the heaviest. Polyurethane stiffened more than the other rubbers on storage or exposure, particularly when used on nylon. Load level had little effect on flexibility.

Departmental Reference: Mat 314

CONTENTS

1 INTRODUCTION

Considerable work has been done on the weathering of uncoated textiles. Little has been published, however, on rubber-coated fabrics, probably because it has generally been assumed that deterioration is considerably less than with uncoated textiles and the problem therefore less urgent. Thus, a neoprene sleeve was found to protect a nylon rope for at least two years[1].

This paucity of data on coated fabrics showed the need for a study of their properties when exposed to various types of weather, and shared work was therefore undertaken by interested parties within the Ministry of Defence (see section 2). The aims of this work were:

(a) to prove a method of exposing rubber-coated fabrics under stress;

(b) to evaluate test methods for assessing the degradation arising therefrom;

(c) to obtain data on cotton and nylon fabrics coated with four types of rubber on exposure.

The present Report summarises the trial and gives the results and their analysis for the flexibility of coated fabrics. A forthcoming RAE publication will deal with the strengths of the fabrics on weathering.

2 DIVISION OF EFFORT

The organisations which participated and their contributions were:

(a) RAE, Cardington: design, construction and testing of a prototype exposure unit; making ready fabrics for despatch to sites; cutting and despatch of fabric pieces to laboratories for testing after exposures.

(b) DR Mat/Mat R6: financial support for supply of eight coated fabrics from a contractor (Dunlop Ltd) and for material for exposure rigs.

(c) RAE, Bedford: making up kits for exposure rigs.

(d) ERDE, Waltham Abbey: writing of trial schedule; exposure of one set of fabrics; liaison with JTRU; transport arrangements for exposure rigs and fabrics; direct-tension adhesion testing of coatings to base fabrics.

(e) JTRU, Queensland: exposure of sets of test fabrics at Cloncurry and Innisfail (UK Trial 81).

(f) MQAD, Woolwich and Chorley: determination of hydrostatic-head permeability, Martindale abrasion resistance and wing-rip tear strength of fabrics.

(g) RAE Materials Department: chairmanship (Mr J.E. Swallow) and secretaryship (Mrs M. Webb) of Working Party (formed in 1968 from members of the Coated Fabrics Sub-Committee which reported via the Rubber Committee to the Joint Services Non-Metallic Materials Research Board; all these committees are now defunct); determination of and analysis of data on flexibility and strength of fabrics.

3 MATERIALS

The following base fabrics were selected as being as similar as possible to each other in mass per unit area:

(a) Nylon to Specification[2] UK/AID/961, designation 85 g. This fabric is required to be scoured and heat set so as to be suitable for subsequent rubber coating. It has a maximum permitted mass per unit area of 88 g/m^2 and a minimum average breaking strength of 230 N/cm.

(b) Cotton to Specification[3] BS 2F (now 3F) 57 C fabric, scoured and rotproofed[4] with 2% lauryl pentachlorophenol. The fabric has a maximum mass per unit area of 80 g/m^2, and a minimum average breaking strength of 75 N/cm.

The base fabrics had the following measured properties (see section 5):

	(i) Thickness, mm	(ii) Mass per unit area, g/m^2	(iii) Bonding length, mm	(iv) Flexural rigidity, N mm	(v) Bonding modulus, N/mm^2
Nylon	0.13	77	29.5	0.019	105
Cotton	0.14	82	20.6	0.007	34

The following rubbers were applied, nominally at 100 g/m^2 to each face, and the resultant coated fabrics identified by Roman numeral:

	Measured total rubber, g/m^2		
	Nylon	Cotton	Mean
(a) Natural	I : 213	V : 190	202
(b) Neoprene	II : 237	VI : 197	217

	Measured total rubber, g/m^2		
	Nylon	Cotton	Mean
(c) Polyesterurethane (PU)	III: 230	VII : 190	210
(d) Chlorosulphonated polyethylene (CSPE)	IV : 241	VIII: 236	238
Mean	230	203	217

The compositions of the rubbers were agreed by the Working Party in consultation with the Rubber Committee, and adopted with slight modifications by the Contractor as given in the Appendix.

4 EXPOSURE CONDITIONS

The rigs on which the specimens were exposed are illustrated in Fig 1. They were constructed so as to carry the specimens, under load, at 45° to the horizontal, and were disposed at the sites so that the fabrics faced the equator.

The specimens were 2 m long by 40 cm wide. Each end was turned twice over a webbing 5 cm wide by 6 mm thick, and cemented to it with a neoprene adhesive. Fabrics were identified by marking their Roman numeral (I to VIII, see section 3) with paint on the under side, and further by notches cut into each end according to a binary code corresponding to 1 to 8. Both methods proved satisfactory; the first made visual identification easier, whilst the latter was more permanent and was not positioned in the exposed portion of the specimen. The specimens were then mounted in the rigs as shown in Fig 2, five bolts being inserted through the fabrics and webbings; this system was adopted so as to minimise slippage, though it was not entirely eliminated and some degree of uneven loading across the specimens had to be accepted.

The lower ends carried masses of concrete or railway sleeper which, inclusive of fittings, were 9.5 kg or 94.6 kg for the nylon fabrics, and 3.2 kg or 32 kg for the cotton fabrics, producing 1% and 10% load levels, relative to the nominal breaking loads, respectively.

Each rig carried three specimens, so that 16 rigs (for 2 fabrics × 4 rubbers × 3 times × 2 load levels/3 specimens per rig) were required at each site for the coated fabrics. In addition, 4 rigs (for 2 fabrics × 3 times × 2 load levels/3 specimens per rig) were supplied to each site for exposures of
016 uncoated fabrics.

Exposures were commenced at ERDE on 4 July 1973, at the hot, dry (HD) desert site at Cloncurry on 27 July 1973, and at the hot,wet cleared (HWC) jungle site at Innisfail on 16 August 1973. Three specimens of each fabric were exposed at each site and load level so that one could be withdrawn after each of 3, 6 and 12 months, and at the end of 6 months a further specimen of each was exposed to give a 6 months' 'stepped' result.

In Australia, 12 of the coated fabrics under 10% load (5 nylon/PU, 2 cotton/PU, 3 cotton/neoprene and 2 cotton/CSPE), and almost all the uncoated fabric specimens at all the sites, broke before their due withdrawal date, and sometimes within a few hours of exposing. These became too badly creased for subsequent reliable measurements of flexibility, and in some cases were lost altogether.

Initial control specimens were taken at the commencement of the trial, and final controls, having been stored flat between sheets of capacitor tissue, in the dark, and without mechanical stress, were taken at the end of 12 months.

The controls and the specimens received back from the exposure sites were cut into test pieces of the required sizes and despatched, flat and wrapped with capacitor tissue, to the various laboratories, no test piece being taken closer than 5 cm from an edge or a clamped region.

The 3 month Australian specimens were not marked so as to distinguish between 1% and 10% loadings. The flexibility results did not obviously separate them, but the breaking strengths[5] of the nylon/natural rubber specimens at 3 months in comparison with the results at the other times gave what was considered to be a reasonable probability to the tabulation in columns K, L, S and T in Tables 1 to 5 (see section 6). Should this be incorrect, however, the effect would be an inflation of the error rather than a reversal of conclusions concerning the influence of load level: there were more marked than unmarked specimens, and these were exposed for longer times so that any effects might be expected to be more noticeable.

From visual examination of the test pieces the most noticeable change was with the PU specimens at Innisfail where there was marked dulling and blotching on both upper and lower faces. This result probably reflects hydrolytic action on PU which would be worst at the hot wet site, and is in line with observations on the effect of PU finishes on nylon yarns[6]. The natural rubber and neoprene coatings on nylon were somewhat dulled and blotched at both Australian sites.

There was only slight dulling or blotching at ERDE, and the CSPE coating was not noticeably altered in appearance at any of the sites.

5 TEST METHODS

The following tests were performed mainly by one operator (BMM) after conditioning the samples for at least 24 h in a room maintained at $20^{o}C$ and 65% relative humidity.

(i) Thickness was measured in mm on a 100 cm^2 piece of each fabric, using a Schopper automatic micrometer exerting a pressure of 0.5 N/cm^2 over a circle of diameter 3.0 cm. Five determinations were made and the mean taken.

(ii) Mass per unit area was calculated in g/m^2 after weighing the above pieces of fabric.

(iii) Bending length was determined by the method given[7] in the 1956 edition of BS Handbook 11, where it is stated that it gives "a measure of draping quality". Two warpway 25mm wide strips were used. The mean of four determinations of the bending angle for a measured length of each strip was found and converted to bending length (the length which would bend to an angle θ such that $\cos\theta = 8 \tan\theta$, or $\theta \approx 7^{o}$), by means of a table given in the Handbook. The mean of the two bending lengths, expressed in mm, was taken.

(iv) Flexural rigidity, stated[7] to be "one of the chief factors in handle", was obtained in N mm by multiplying the cube of the mean bending length (iii) by the mass per unit area (ii) and a constant ($g/10^9$, where $g = 9.81\ m/s^2$).

(v) Bending modulus, which according to Ref 7 "characterises fullness and paperiness", was obtained in N/mm^2 by dividing the flexural rigidity (iv) by the cube of the thickness (i) and a constant (1/12).

6 METHOD OF ANALYSIS OF RESULTS

The loss of 12 specimens nullified the possibility of analysing all the exposure results together. Nevertheless, it was still possible to analyse five complete factorial sub-experiments[8] in the following sets:

(a) The 'controls' (Tables 1 to 5, columns A and B).

016 (b) All the '3 month' exposures (Tables 1 to 5, columns C, D, K, L, S, T).

(c) All exposures under '1%' load (Tables 1 to 5, columns C, E, G, I, K, M, O, Q, S, U, W, Y).

(d) All exposures with 'natural rubber' coating (Tables 1 to 5, columns C to Z, rows I and V only).

(e) All exposures at 'ERDE' (Tables 1 to 5, columns C to J).

The controls were also incorporated into the analysis by considering them in conjunction with the results at 1% loading at each site, giving three more sub-experiments:

(f) "ERDE, 1%, with controls" (Tables 1 to 5, columns A, B, C, E, G, I).

(g) "Cloncurry, 1%, with controls" (Tables 1 to 5, columns A, B, K, M, O, Q).

(h) "Innisfail, 1%, with controls" (Tables 1 to 5, columns A, B, S, U, W, Y).

It will be noted that (f), (g) and (h) cannot satisfactorily be combined, nor can (a) be included with (b), (c), (d) or (e) because of the usual unavoidable inadequacies of the factorial arrangement (ie in the construction of the tree diagram) in accommodating controls.

These eight sets were subjected to analysis of variance by computer for each of the five properties, viz thickness, mass per unit area, bending length, flexural rigidity and bending modulus.

7 ANALYSIS OF ERRORS

Table 6 gives the error variances for the analyses[8]. The 3 month results had the lowest errors for thickness and mass per unit area, whilst the natural rubber results were lowest for flexibility. Innisfail had the highest errors for flexibility.

Coefficients of variation are also given in Table 6. For thickness and mass per unit area, they were about 2 to 3%, for bending length generally about twice this, and for flexural rigidity and bending modulus mainly about tenfold.

8 RESULTS AND DISCUSSION

8.1 Thickness

The measured thicknesses are given in Table 1, and analysis of variance for each set in Table 7. The coated nylon fabrics were thicker than the coated

cotton, usually at the 99.9% level of probability, reflecting the greater uptake of rubber on nylon (section 3), and the thicknesses in the natural rubber set (d) were less than in the other sets.

Mean thickness, mm

Fabric type	All sets except 'natural rubber'	'Natural rubber'
Nylon	0.267	0.257
Cotton	0.237	0.226

The effect of rubber type was also significant, usually at the 99.9% level of probability. The PU and CSPE coated fabrics were thicker than the natural rubber and neoprene, but there were no significant differences between sets (a) *to* (h) except (d).

Rubber type	Mean thickness, mm
PU	0.262
CSPE	0.262
Neoprene	0.244
Natural	0.239
Mean difference required for significance at 99.9% level	0.009

There was no evidence that thickness was affected by the site, or by the interactions between fabric and time, fabric and site, fabric and load, rubber and time, rubber and load, time and site, time and load, or site and load. There was only slight evidence that thickness was affected by the time, the load, or by the interactions between fabric and rubber or rubber and site.

8.2 Mass per unit area

The masses per unit area are given in Table 2, and analysis of variance for each set in Table 8. The coated nylon fabrics were heavier than the coated cotton, usually at the 99.9% level of probability (*cf* section 8.1), and the masses in the natural rubber set (d) were lower than in the other sets.

Mean mass per unit area, g/m^2

	Fabric type	All sets except natural rubber	Natural rubber
016	Nylon	300	269
	Cotton	280	260

The effect of rubber type was also significant, usually at the 99.9% level of probability. The order was CSPE > neoprene > PU > natural, this reflecting the higher densities of the chlorinated rubbers. There was also evidence of weight loss for all the rubbers except CSPE in all sets, compared with the controls (a):

Mean mass per unit area, g/m^2

Rubber type	Sets (b) to (h), except (d)	Controls (set (a))
CSPE	315	316
Neoprene	291	300
PU	281	290
Natural	266	280
Mean difference required at 99.9% level of probability	9	

The weight loss with time was most significant at Innisfail (set (h)), for which the results were:

	Time, months					
	Initial	Final	3	6	12	6 'stepped'
Mass per unit area, g/m^2	296	297	285	283	274	288

There was no evidence that mass per unit area was affected by the load or by the interactions between fabric and time, fabric and site, fabric and load, rubber and time, rubber and load, time and site, time and load, or site and load.

8.3 Bending length

The bending lengths are given in Table 3, and analysis of variance for each set in Table 9. The bending lengths of the coated controls were on the average 30% higher than of the uncoated controls (section 3). The bending lengths of the coated nylon fabrics were greater than of the coated cotton, usually at the 99.9% level of probability, possibly partly due to the greater amount of rubber on the nylon (section 3). The results in the natural rubber set (d) tended to be lower and those in the other sets higher than those in the control set (a). The mean values in mm were:

Fabric type	Controls	Natural rubber	Others
Nylon	36.2	33.8	39.5
Cotton	28.2	25.1	30.2

The effect of rubber type was also significant, usually at the 99.9% level of probability. The PU had a higher bending length than the neoprene, which in turn had a higher bending length than CSPE or natural. This result did not appear to be due entirely to the amount of rubber, since the order did not correlate with the order of rubber masses (sections 3 and 8.2).

Rubber type	Controls	3 months	1%	ERDE	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail, 1%, with controls
PU	43.3	46.0	51.2	45.5	45.6	49.8	50.2
Neoprene	29.5	32.7	34.1	33.0	31.7	32.9	33.1
CSPE	29.1	29.9	30.1	29.6	29.5	30.1	29.6
Natural	27.0	28.0	29.4	29.3	28.7	28.4	28.7
Difference required at 99.9% level of probability	17.0	3.0	2.0	3.1	2.1	2.9	3.8

Exposed specimens had increased bending length compared with the controls, and this tended to increase with time of exposure, though not always significantly at the 99.9% level of probability.

Time, months	1%	Natural rubber	ERDE	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail, 1%, with controls
Initial				30.9	30.9	30.9
Final				33.6	33.6	33.6
3	34.2	28.0	33.8	34.1	34.3	34.1
6	36.4	29.0	33.7	33.4	37.3	38.4
12	37.4	31.2	34.9	36.1	38.2	37.8
6 'stepped'	36.8	29.7	35.0	35.2	37.4	37.8
Difference required at 99.9% level of probability	2.0	1.9	3.1	2.7	3.6	4.7

The mean bending lengths at both Australian sites were greater than at ERDE in the '1%' set (c).

Site	Bending length, mm
ERDE	34.7
Cloncurry	36.8
Innisfail	37.0
Difference required at 99.9% level of probability	1.8

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There was evidence that PU on nylon had a higher bending length than expected from these components. Thus, from the '1%' set, the mean values in mm were:

	Rubber type			
Fabric type	Natural	Neoprene	PU	CSPE
Nylon	34.1	39.0	59.2	31.9
Cotton	24.7	29.2	43.2	28.3

There was no evidence that bending length was affected by the load, or by the interactions between fabric and time, fabric and site, rubber and load, time and load, or site and load; there was only slight evidence that bending length was affected by the interactions between fabric and load, or time and site.

8.4 Flexural rigidity

The flexural rigidities are given in Table 4, and analysis of variance for each set in Table 10. For the coated controls, the values were on average about an order of magnitude higher than for the uncoated controls (section 3), due partly to increased bending length and partly to increased mass per unit area. Those variance ratios which were significant were similar to those for bending length, though the values were generally lower because of the higher errors.

The flexural rigidities of the coated nylon fabrics were higher than those of the coated cotton, usually at the 99.9% level of probability, the mean values in N mm being:

Fabric	Controls	3 months	1%	Natural rubber	ERDE	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail, 1%, with controls
Nylon	0.174	0.205	0.245	0.103	0.195	0.200	0.235	0.228
Cotton	0.069	0.074	0.099	0.040	0.080	0.076	0.094	0.097

The effect of rubber type was also significant, usually at the 99.9% level of probability. The order was PU > neoprene > CSPE > natural, though CSPE was not significantly higher than natural.

Rubber type	Controls	3 months	1%	ERDE	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail, 1%, with controls
PU	0.270	0.304	0.407	0.291	0.305	0.394	0.385
Neoprene	0.080	0.106	0.124	0.109	0.099	0.111	0.117
CSPE	0.077	0.085	0.086	0.081	0.081	0.087	0.081
Natural	0.059	0.063	0.071	0.070	0.068	0.067	0.067

Flexural rigidity tended to increase during exposure in sets (d), (f), (g) and (h), the mean values in N mm being:

Time months	Natural rubber	ERDE, 1%	Cloncurry, 1%	Innisfail, 1%
Initial	0.060	0.097	0.097	0.097
Time	0.058	0.146	0.146	0.146
3	0.063	0.142	0.148	0.140
6	0.069	0.123	0.211	0.211
12	0.080	0.163	0.201	0.174
6 'stepped'	0.074	0.158	0.187	0.206

The PU on nylon had a higher flexural rigidity than expected from these components, the interaction between fabric and rubber usually being significant at the 99.9% level of probability. Thus, from the 3 month set, the mean values in N mm were:

	Rubber type			
Fabric type	Natural	Neoprene	PU	CSPE
Nylon	0.094	0.148	0.474	0.104
Cotton	0.032	0.064	0.133	0.066

There was no evidence that flexural rigidity was affected by the load, or by the interactions between fabric and time, fabric and site, rubber and load, or time and load.

8.5 Bending modulus

The bending moduli are given in Table 5, and analysis of variance for each set in Table 11. The bending moduli of the coated nylon fabrics were not, on the average, significantly higher than those of the uncoated fabrics (see section 3), though those of the cotton fabrics probably were. This reflects
016 the introduction of thickness into the calculations. Those variance ratios which

were significant were similar to those for bending length, though the values were generally lower, and also usually lower than for flexural rigidity.

The bending moduli of the coated nylon fabrics were higher than those of the cotton, usually at the 99.9% level of probability, the mean values in N/mm^2 being:

Fabric type	Controls	3 months	1%	Natural rubber	ERDE	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail, 1%, with controls
Nylon	109	117	147	73	116	123	141	138
Cotton	58	65	84	41	71	67	81	79

The effect of rubber type was also significant, usually at the 99.9% level of probability. The PU had higher values than the other rubbers, and neoprene often was higher than CSPE or natural.

Rubber type	Controls	3 months	1%	ERDE	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail, 1%, with controls
PU	173	181	252	176	188	250	238
Neoprene	63	78	95	87	79	84	90
CSPE	50	54	56	56	56	55	51
Natural	48	50	59	57	58	55	54

Time was significant, sometimes at the 99.9% level of probability, the effect being an increase in bending modulus:

Bending modulus, N/mm^2

Time, months	Natural rubber	ERDE, 1%, with controls	Cloncurry, 1%, with controls	Innisfail 1%, with controls
Initial	48	65	65	65
Final	49	103	103	103
3	50	92	97	90
6	54	84	141	140
12	65	116	135	111
6 'stepped'	60	112	126	142

The PU on nylon gave a higher bending modulus than expected from these components, the interaction between fabric and rubber often being significant at the 99.9% level of probability. Thus, for the 3 months set, the mean values in N/mm^2 were:

	Rubber type			
Fabric type	Natural	Neoprene	PU	CSPE
Nylon	66	95	249	56
Cotton	34	60	112	52

There was no evidence that bending modulus was affected by the interactions between fabric and time, fabric and site, or time and site; there was only slight evidence that bending modulus was affected by the site, the load, or the interactions between rubber and load, time and load, or site and load.

9 CONCLUSIONS

(1) A method for exposure of coated fabrics has been proved. Data on flexibility of a nylon and a cotton fabric coated with natural rubber, neoprene, polyurethane or chlorosulphonated polyethylene have been determined after weathering for up to 1 year in UK and Australia.

(2) Throughout, the coated nylon fabrics were thicker, heavier and less flexible than the coated cotton fabrics. Fabrics coated with polyurethane or chlorosulphonated polyethylene tended to be thicker than those coated with natural rubber or neoprene whilst those coated with chlorosulphonated polyethene were the heaviest.

(3) Polyurethane stiffened more than the other rubbers on storage or exposure, particularly when used on nylon.

(4) Stiffening tended to increase with time of exposure or storage.

(5) Stiffening after weathering in UK was less than that in Australia.

(6) Load level had little effect on stiffness.

Acknowledgments

The authors thank Miss B.M. McInroy, formerly of Materials Department, RAE, for assistance with the experimental work, and Mr J.H. Cadwell, Mathematics Department, RAE, for arranging the computer programmes.

Appendix

COMPOSITION OF RUBBERS BY MASS

Ingredient	Natural	Neoprene	PU	CSPE
Natural rubber smoked sheet	58			
Neoprene		54.5		
Polyurethane (PU)			77	
Chlorosulphonated polyethylene (CSPE)				50
Black	34.8	32.7	22.8	7.5
Antioxidant (phenol condensation product)	1.25	1.06		
Sulphur	0.75			
Mercaptobenzthiazole	0.5			
2-Mercaptoimidazoline		0.25		
Tetramethylthiuramdisulphide	0.125			1.0
Stearic acid	0.5		0.25	
Pentaerythritol				1.5
Paraffin wax	1.25	1.06		
Process oil		5.5		
Polyisocyanate phenol adduct			15.5	
Magnesium oxide		2.2		2.0
Zinc oxide	2.8	2.8		
Whiting				38
Lauryl pentachlorophenol, %	2	2	2	2

Table 1

THICKNESS OF FABRICS, mm

Site	Controls		ERDE								Cloncurry								Innisfail							
Time, months	Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load level, %			1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Coated fabric (See section 3)																										
I Nyl/Nat	0.26	0.25	0.26	0.27	0.26	0.26	0.24	0.26	0.24	0.26	0.26	0.25	0.25	0.28	0.25	0.27	0.26	0.26	0.26	0.25	0.25	0.26	0.25	0.26	0.26	0.26
II Nyl/Neo	0.26	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.26	0.26	0.26	0.27	0.26	0.26	0.26	0.26	0.26	0.27	0.26	0.26	0.26	0.27	0.25	0.28
III Nyl/PU	0.28	0.27	0.28	0.29	0.28	0.29	0.28	0.28	0.28	0.29	0.28	0.28	0.28	(0.28)	0.28	(0.28)	0.28	-	0.28	0.29	0.28	0.29	0.29	-	0.27	(0.28)
IV Nyl/CSPE	0.27	0.27	0.27	0.27	0.28	0.28	0.26	0.28	0.27	0.26	0.28	0.28	0.26	0.29	0.28	0.28	0.28	0.28	0.29	0.29	0.26	0.27	0.27	0.29	0.28	0.29
V Cot/Nat	0.23	0.22	0.22	0.23	0.22	0.23	0.23	0.22	0.22	0.23	0.22	0.22	0.23	0.23	0.22	0.23	0.22	0.23	0.22	0.22	0.22	0.24	0.24	0.24	0.22	0.22
VI Cot/Neo	0.23	0.24	0.24	0.24	0.23	0.23	0.22	0.23	0.23	0.23	0.22	0.24	0.22	(0.24)	0.24	-	0.22	0.23	0.23	0.23	0.22	0.25	0.24	0.22	0.22	0.23
VII Cot/PU	0.25	0.24	0.25	0.24	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	(0.25)	0.24	0.25	0.24	0.24	0.26	(0.25)	0.26	0.24	0.24	0.24
VIII Cot/CSPE	0.26	0.25	0.24	0.25	0.24	0.25	0.24	0.25	0.24	0.24	0.24	0.24	0.26	-	0.25	-	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.26	0.25

\- specimen lost

( ) specimen broken and creased

Table 2

MASS PER UNIT AREA OF FABRICS, g/m^2

Site	Controls		ERDE								Cloncurry								Innisfail							
Time, months	Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load level, %			1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Coated fabric (see section 3)																										
I Nyl/Nat	290	289	278	282	282	260	257	253	269	267	271	270	263	279	267	273	282	278	266	272	274	269	252	250	278	274
II Nyl/Neo	314	317	304	299	303	303	306	307	306	309	301	305	308	308	316	301	304	300	314	315	313	300	300	298	304	305
III Nyl/PU	307	303	294	288	290	286	300	284	295	293	290	291	293	(289)	288	(294)	281	-	283	282	270	258	248	-	289	(285)
IV Nyl/CSPE	318	319	322	319	335	328	316	334	329	305	328	319	309	330	325	319	329	320	327	335	309	315	308	322	328	322
V Cot/Nat	272	267	266	262	250	257	259	244	264	273	264	258	275	267	262	262	263	264	248	257	254	264	248	254	264	259
VI Cot/Neo	279	291	272	272	272	269	272	279	281	282	265	284	270	(283)	273	-	270	276	274	267	269	289	272	(268)	258	280
VII Cot/PU	272	279	278	262	276	278	273	273	275	273	274	271	279	274	273	(267)	283	285	263	263	264	(249)	258	247	274	270
VIII Cot/CSPE	318	311	296	304	299	301	300	301	300	303	302	306	322	-	318	-	316	325	305	318	314	317	306	299	313	306

- specimen lost

( ) specimen broken and creased

Table 3

BENDING LENGTH OF FABRICS, mm

Site	Controls		ERDE								Cloncurry								Innisfail							
Time, months	Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load level, %			1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
<u>Coated fabric</u> (see section 3)																										
I Nyl/Nat	31.4	31.0	33.5	33.2	33.5	32.4	35.0	33.5	35.0	32.0	31.2	32.8	34.0	32.5	35.0	34.5	35.0	33.5	32.2	33.4	34.0	34.9	36.0	35.5	34.5	35.0
II Nyl/Neo	32.0	33.5	37.5	36.1	35.9	35.9	38.5	36.0	37.0	37.5	36.1	34.8	38.5	37.5	41.0	39.5	41.0	39.5	37.5	37.6	46.5	38.0	39.0	39.0	39.0	38.5
III Nyl/PU	44.4	57.5	55.9	50.2	49.7	50.6	57.0	44.6	57.5	56.5	58.2	53.6	67.0	-	61.0	-	60.5	-	55.8	56.6	63.5	64.0	58.0	-	66.0	-
IV Nyl/CSPE	29.8	30.5	32.1	32.0	31.5	32.0	32.0	30.5	31.0	32.0	32.2	32.3	32.0	31.0	33.0	32.0	33.0	34.0	31.0	31.9	31.0	31.0	32.0	32.0	32.0	32.5
V Cot/Nat	23.2	22.5	22.8	23.6	25.5	27.7	27.0	24.5	24.0	25.0	23.6	24.3	22.0	23.5	27.0	27.5	24.5	24.5	22.5	22.4	23.5	25.0	28.5	30.0	25.5	27.5
VI Cot/Neo	26.9	25.5	28.2	30.2	27.0	28.8	29.0	30.5	29.0	31.0	29.0	28.0	29.5	-	31.5	-	30.0	32.5	27.8	29.5	29.0	32.0	30.0	-	30.5	31.5
VII Cot/PU	32.7	39.0	35.0	35.0	36.8	38.4	42.0	42.0	40.0	36.5	36.0	38.7	47.0	48.5	48.5	-	46.0	52.5	38.5	38.2	51.5	-	50.5	45.0	46.0	48.0
VIII Cot/CSPE	27.0	29.0	27.8	27.2	27.5	26.4	28.0	27.5	28.0	28.5	28.4	28.4	28.5	-	29.0	-	29.0	28.5	27.6	28.5	28.0	28.5	28.5	28.5	29.0	28.5

\- no measurement possible (specimen lost or badly creased)

Table 4

FLEXURAL RIGIDITY OF FABRICS, N mm

Site	Controls		ERDE								Cloncurry								Innisfail							
Time, months	Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load level, %			1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Coated fabric (see section 3)																										
I Nyl/Nat	0.088	0.085	0.102	0.101	0.104	0.087	0.109	0.092	0.114	0.087	0.081	0.094	0.100	0.094	0.114	0.109	0.118	0.103	0.087	0.099	0.104	0.112	0.114	0.110	0.113	0.114
II Nyl/Neo	0.101	0.118	0.157	0.138	0.138	0.138	0.174	0.142	0.154	0.160	0.139	0.126	0.174	0.160	0.216	0.181	0.203	0.181	0.162	0.165	0.306	0.162	0.175	0.175	0.175	0.174
III Nyl/PU	0.264	0.560	0.504	0.357	0.350	0.364	0.545	0.244	0.560	0.513	0.562	0.441	0.856	-	0.646	-	0.608	-	0.481	0.501	0.678	0.669	0.478	-	0.818	-
IV Nyl/CSPE	0.083	0.089	0.104	0.103	0.103	0.105	0.103	0.092	0.096	0.100	0.107	0.106	0.100	0.096	0.116	0.103	0.116	0.123	0.096	0.107	0.091	0.094	0.100	0.103	0.106	0.108
V Cot/Nat	0.033	0.030	0.031	0.034	0.040	0.053	0.050	0.035	0.035	0.041	0.034	0.036	0.029	0.034	0.050	0.053	0.038	0.038	0.028	0.028	0.032	0.040	0.057	0.066	0.029	0.053
VI Cot/Neo	0.053	0.047	0.060	0.073	0.053	0.063	0.065	0.078	0.067	0.082	0.063	0.061	0.068	-	0.083	-	0.072	0.094	0.058	0.067	0.065	0.093	0.072	-	0.072	0.086
VII Cot/PU	0.093	0.163	0.116	0.111	0.135	0.154	0.196	0.196	0.176	0.129	0.126	0.154	0.285	0.302	0.302	-	0.267	0.412	0.147	0.143	0.348	-	0.328	0.224	0.258	0.293
VIII Cot/CSPE	0.061	0.074	0.063	0.060	0.061	0.054	0.065	0.061	0.065	0.068	0.068	0.069	0.073	-	0.077	-	0.077	0.075	0.063	0.072	0.067	0.073	0.070	0.068	0.074	0.070

\- no measurement possible (specimen lost or badly creased)

Table 5

BENDING MODULUS OF FABRICS, N/mm^2

Site	Controls		ERDE								Cloncurry								Innisfail							
Time, months	Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load level, %			1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Coated fabric (see section 3)																										
I Nyl/Nat	64	65	70	61	71	60	95	63	99	59	55	72	77	54	87	66	85	70	59	76	76	77	84	75	82	77
II Nyl/Neo	69	91	114	94	100	94	118	98	118	123	95	82	118	98	140	124	138	131	99	106	208	117	119	106	134	95
III Nyl/PU	136	341	261	176	191	179	297	133	305	263	323	241	489	-	352	-	332	-	250	246	370	329	235	-	498	-
IV Nyl/CSPE	51	54	64	63	56	58	67	50	59	68	55	58	64	46	63	54	60	67	47	52	58	57	61	51	58	53
V Cot/Nat	33	32	33	33	49	53	49	39	40	41	36	41	29	34	57	52	40	37	31	32	34	35	52	58	31	56
VI Cot/Neo	52	41	52	64	52	62	73	77	66	80	66	56	72	-	76	-	75	93	57	66	73	72	66	-	76	84
VII Cot/PU	72	142	90	96	104	118	171	171	153	112	102	134	233	263	247	-	226	317	128	124	252	-	224	182	210	255
VIII Cot/CSPE	42	54	54	46	53	42	56	48	56	56	59	56	47	-	59	-	55	51	46	49	46	47	51	52	48	54

\- no measurement possible (specimen lost or badly creased)

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Table 6

ANALYSIS OF ERRORS

(a) Variances

	Set analysed (see section 6)							
Property (see section 6)	(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls
(i) Thickness	$39.6/10^6$	$22.2/10^6$	$48.6/10^6$	$57.6/10^6$	$34.7/10^6$	$51.3/10^6$	$43.2/10^6$	$37.1/10^6$
(ii) Mass per unit area	22.2	15.1	48.1	57.0	55.4	60.8	64.2	44.5
(iii) Bending length	3.44	1.48	2.97	0.58	3.34	1.66	3.05	5.22
(iv) Flexural rigidity	$30.8/10^4$	$5.6/10^4$	$24.8/10^4$	$0.2/10^4$	$12.7/10^4$	$11.4/10^4$	$21.3/10^4$	$31.8/10^4$
(v) Bending modulus	1064	261	994	29	327	312	813	1320
No. of degrees of freedom in error	3	6	18	6	9	15	15	15

(b) Coefficients of variation

(i) Thickness	2.5	1.9	2.8	3.1	2.3	2.9	2.6	2.4
(ii) Mass per unit area	1.6	1.4	2.4	2.8	2.6	2.7	2.7	2.3
(iii) Bending length	5.8	3.6	4.8	2.6	5.3	3.8	5.0	6.4
(iv) Flexural rigidity	45.8	17.0	29.0	6.2	25.8	24.5	28.0	34.8
(v) Bending modulus	39.0	17.8	27.2	9.4	19.2	18.5	25.7	33.5

Table 7

VARIANCE RATIOS FOR THICKNESS

Factor	No. of levels	No. of results per level	No. of degrees of freedom	Set (see section 6)							
				(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls
Fabric F	2	8	1	57.0_G							
	2	24	1		645_{GG}		209_{GG}		182_{GG}	243_{GG}	209_{GG}
	2	32	1					450_{GG}			
	2	48	1			432_{GG}					
Rubber R	4	4	3	12.4							
	4	12	3		74.3_{GG}				29.7_{GG}	39.8_{GG}	57.6_{GG}
	4	16	3					54.5_{GG}			
	4	24	3			79_{GG}					
Time T	2	8	1	3.9_N							
	4	12	3				0.9_N				
	4	16	3					5.0			
	4	24	3			0.9_N					
	6	8	5						2.1_N	1.0_N	3.1
Site S	3	16	2		4.9_N		0.3_N				
	3	32	2			3.2_N					
Load L	2	24	1		2.3_N		9.2				
	2	32	1					8.8			
FR	8	2	3	1.4_N							
	8	6	3		4.6_N				0.9_N	3.4	4.1
	8	8	3					4.4			
	8	12	3			3.3					
FT	4	4	1	0.2_N							
	8	6	3				1.3_N				
	8	8	3					0.5_N			
	8	12	3			2.3_N					
	12	4	5						0.7_N	2.1_N	2.1_N
FS	6	8	2		1.5_N		0.7_N				
	6	16	2			1.6_N					
FL	4	12	1		0.1_N		0.7_N				
	4	16	1					0.7_N			
RT	8	2	3	0.6_N							
	16	4	9					0.6_N			
	16	6	9			1.0_N					
	24	2	15						0.4_N	0.6_N	1.6_N
RS	12	4	6		5.6						
	12	8	6			1.8_N					
RL	8	6	3		0.6_N						
	8	8	3					1.3_N			
TS	12	4	6				1.3_N				
	12	8	6			2.1_N					
TL	8	6	3				1.3_N				
	8	8	3					0.2_N			
SL	6	8	2		0.4_N		0.5_N				

<u>Note</u>: *For error variances, see Table 6.*

GG Significant at 99.9% level of probability.

G Significant at 99% level of probability.

No suffix Significant at 95% level of probability.

N Significant at less than 95% level of probability.

Table 8

VARIANCE RATIOS FOR MASS PER UNIT AREA

Factor	Set (see section 6)							
	(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls
Fabric F	79.6_{G}	380_{GG}	167_{GG}	19.0_{G}	114_{GG}	93_{GG}	55.6_{GG}	94_{GG}
Rubber R	44.6_{G}	346_{GG}	222_{GG}		114_{GG}	63.3_{GG}	69.5_{GG}	119_{GG}
Time T	0.1_{N}		3.7	6.4	0.8_{N}	2.8	1.9_{N}	13.4_{GG}
Site S		0.1_{N}	8.5_{G}	3.7_{N}				
Load L		0.4_{N}		0.0_{N}	1.3_{N}			
FR	6.8_{N}	14.5_{G}	17.6_{GG}		5.5	2.2_{N}	7.7_{G}	10.7_{GG}
FT	0.2_{N}		1.6_{N}	0.9_{N}	0.9_{N}	0.4_{N}	1.0_{N}	2.1_{N}
FS		2.4_{N}	1.9_{N}	0.1_{N}				
FL		0.5_{N}		0.1_{N}	1.3_{N}			
RT	1.1_{N}		1.0_{N}		1.9_{N}	0.6_{N}	0.7_{N}	2.2_{N}
RS		8.4_{G}	3.1					
RL		2.2_{N}			0.6_{N}			
TS			1.9_{N}	1.6_{N}				
TL				0.1_{N}	0.1_{N}			
SL		2.7_{N}		0.5_{N}				

Note: For number of levels, number of results per level, and numbers of degrees of freedom, see Table 7.

For error variances, see Table 6.

GG Significant at 99.9% level of probability.

G Significant at 99% level of probability.

No suffix Significant at 95% level of probability.

N Significant at less than 95% level of probability.

Table 9

VARIANCE RATIOS FOR BENDING LENGTH

Factor	Set (see section 6)							
	(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls
Fabric F	74.1_{G}	792_{GG}	760_{GG}	1597_{GG}	359_{GG}	600_{GG}	340_{GG}	184_{GG}
Rubber R	64.7_{G}	536_{GG}	842_{GG}		278_{GG}	452_{GG}	381_{GG}	233_{GG}
Time T	8.4_{N}		15.7_{GG}	37.4_{GG}	2.3_{N}	15.3_{GG}	21.3_{GG}	14.1_{GG}
Site S		1.2_{N}	18.0_{GG}	6.9				
Load L		0.0_{N}		0.4_{N}	2.3_{N}			
FR	8.1_{N}	72.3_{GG}	51.9_{GG}		22.8_{GG}	49.8_{GG}	29.3_{GG}	12.9_{GG}
FT	1.5_{N}		2.2_{N}	4.0_{N}	2.4_{N}	2.6_{N}	1.5_{N}	1.1_{N}
FS		0.6_{N}	0.2_{N}	0.4_{N}				
FL		3.6_{N}		7.9	5.0			
RT	6.9_{N}		3.5_{G}		1.1_{N}	4.7_{G}	5.6_{G}	3.8_{G}
RS		2.9_{N}	8.8_{GG}					
RL		1.3_{N}			2.0_{N}			
TS			3.1	5.3				
TL				1.7_{N}	1.9_{N}			
SL		1.4_{N}		3.5_{N}				

Note: For number of levels, number of results per level, and number of degrees of freedom, see Table 7.

For error variances, see Table 6.

GG Significant at 99.9% level of probability.

G Significant at 99% level of probability.

No suffix Significant at 95% level of probability.

N Significant at less than 95% level of probability.

Table 10

VARIANCE RATIOS FOR FLEXURAL RIGIDITY

Factor	Set (see section 6)							
	(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls
Fabric F	14.1	373_{GG}	206_{GG}	2417_{GG}	166_{GG}	161_{GG}	112_{GG}	65_{GG}
Rubber R	12.8	265_{GG}	242_{GG}		135_{GG}	131_{GG}	134_{GG}	84_{GG}
Time T	3.1_{N}		3.6	31.3_{GG}	1.8_{N}	4.3	6.9_{G}	4.7_{G}
Site S		1.2_{N}	6.3_{G}	4.5_{N}				
Load L		1.4_{N}		0.0_{N}	4.1_{N}			
FR	4.8_{N}	108_{GG}	55.2_{GG}		38.4_{GG}	44.8_{GG}	35.8_{GG}	16.6_{GG}
FT	1.2_{N}		0.7_{N}	4.2_{N}	1.6_{N}	1.6_{N}	1.4_{N}	1.4_{N}
FS		0.2_{N}	0.5_{N}	1.6_{N}				
FL		3.3_{N}		14.0_{G}	4.6_{N}			
RT	2.6_{N}		1.7_{N}		1.2_{N}	2.4	3.6_{G}	2.5
RS		1.6_{N}	4.0_{G}					
RL		2.2_{N}			3.0_{N}			
TS			1.7_{N}	5.6				
TL				2.9_{N}	1.4_{N}			
SL		0.4_{N}		9.9				

Note: For number of levels, number of results per level, and number of degrees of freedom, see Table 7.

For error variances, see Table 6.

GG Significant at 99.9% level of probability.

G Significant at 99% level of probability.

No suffix Significant at 95% level of probability.

N Significant at less than 95% of probability.

Table 11

VARIANCE RATIOS FOR BENDING MODULUS

Factor	Set (see section 6)							
	(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls
Fabric F	9.6_N	124_{GG}	94_{GG}	419_{GG}	99_{GG}	120_{GG}	53_{GG}	31.8_{GG}
Rubber R	13.4	173_{GG}	207_{GG}		157_{GG}	152_{GG}	128_{GG}	71_{GG}
Time T	5.3_N		5.7_G	17.6_G	5.9	9.3_{GG}	8.1_{GG}	5.3_{GG}
Site S		1.3_N	5.2	0.9_N				
Load L		0.8_N		6.9	10.0			
FR	3.0_N	39.1_{GG}	21.9_{GG}		18.2_{GG}	28.8_{GG}	1.7_N	6.7_G
FT	1.5_N		1.0_N	2.2_N	2.9_N	1.8_N	1.0_N	1.3_N
FS		0.1_N	0.1_N	1.0_N				
FL		2.8_N		18.8_G	8.9			
RT	4.1_N		2.1_N		2.0_N	4.2_G	4.0_G	2.7
RS		2.6_N	4.9_G					
RL		1.8_N			4.0			
TS			2.2_N	1.4_N				
TL				5.3	1.9_N			
SL		0.4_N		9.9				

Note: For number of levels, number of results per level, and number of degrees of freedom, see Table 7.

For error variances, see Table 6.

GG Significant at 99.9% level of probability.

G Significant at 99% level of probability.

No suffix Significant at 95% level of probability.

N Significant at less than 95% of probability.

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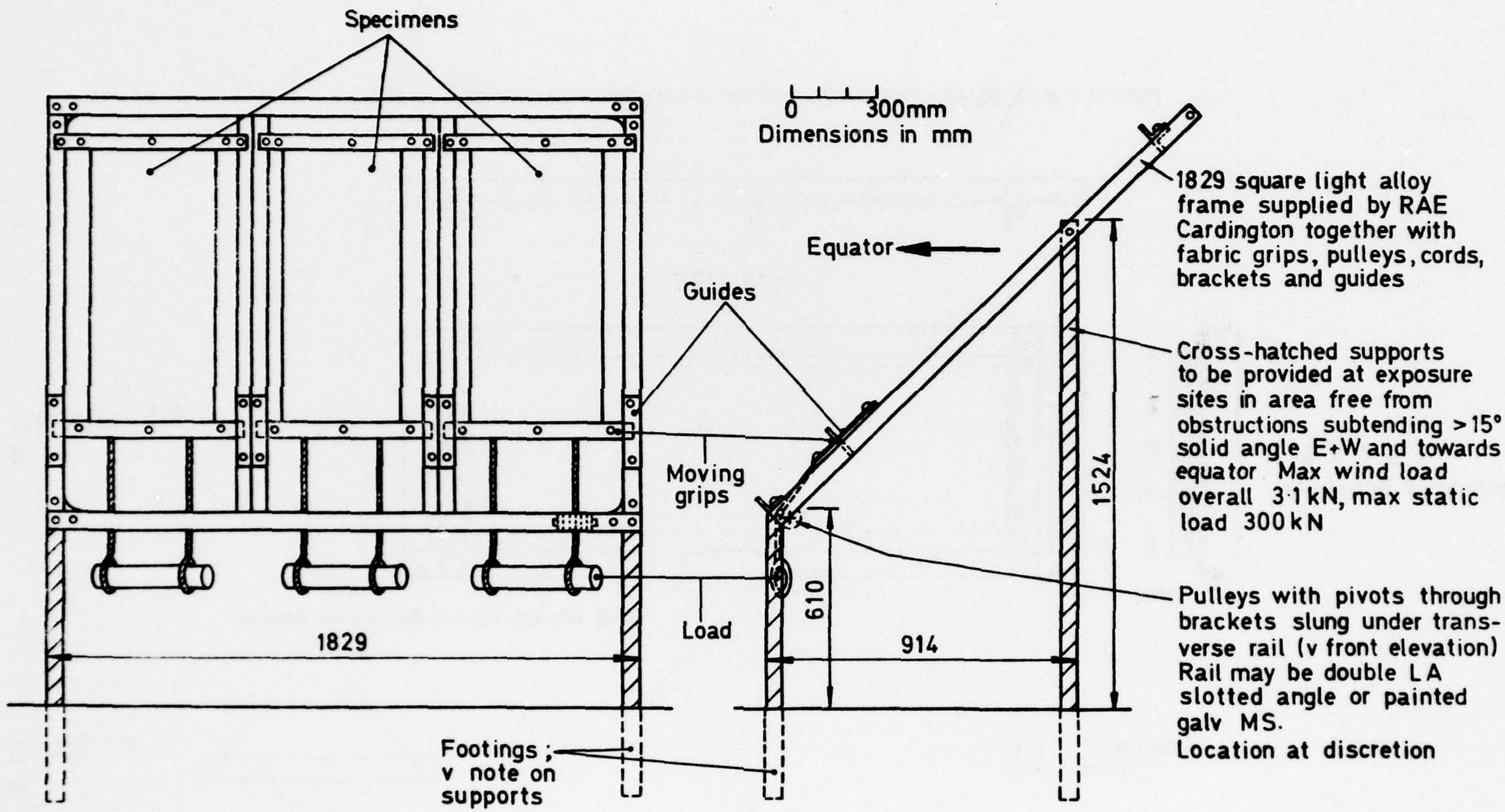

Fig 1 Stress rigs and method of mounting (from ERDE trial schedule, based on RAE Cardington drawings)

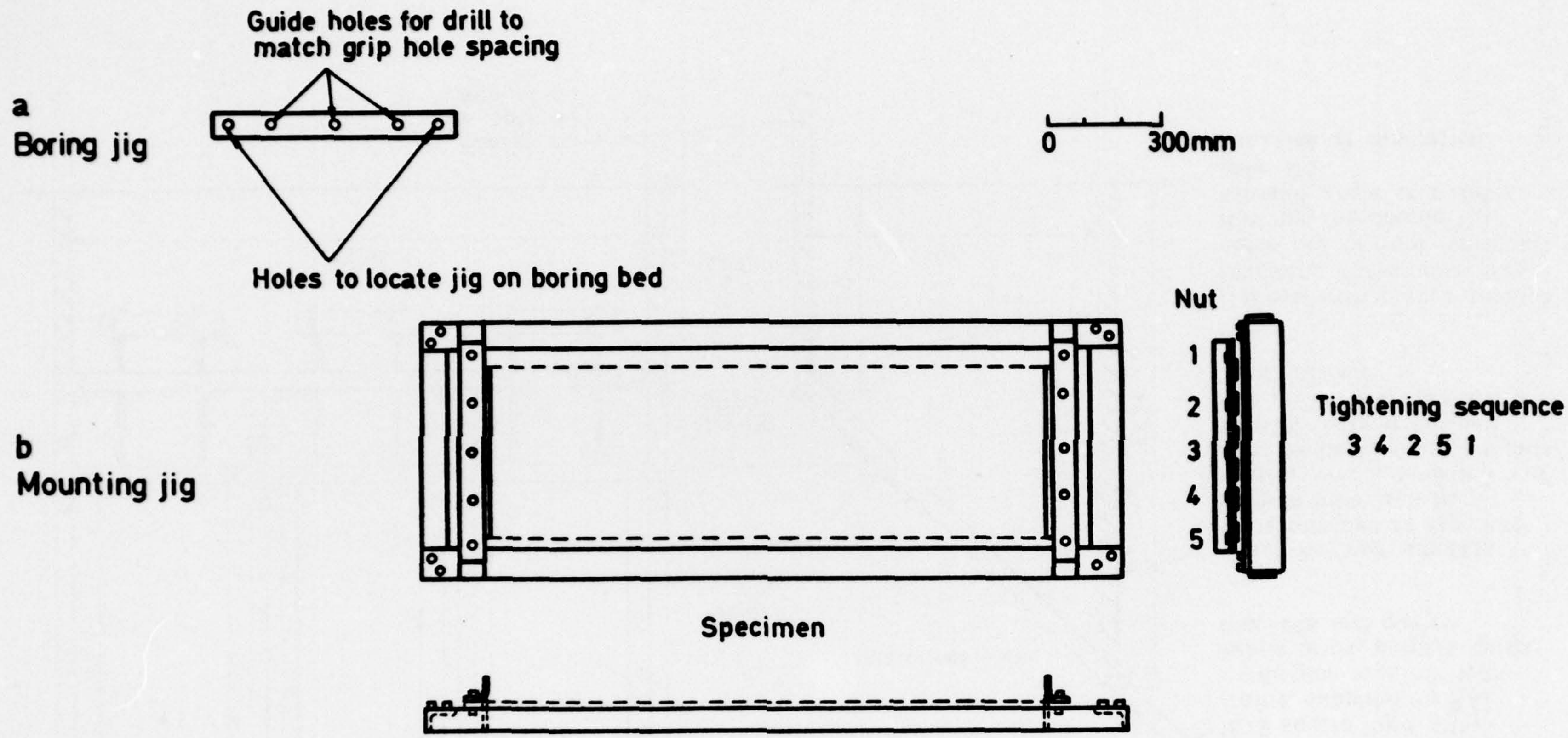

Fig 2 Jigs for drilling and mounting specimens (from ERDE trial schedule)

REPORT DOCUMENTATION PAGE

Overall security classification of this page

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17. Abstract

The effects of 1 year of weathering on the flexibility of rubber-coated fabrics was studied in 208 combinations of base fabric, rubber type, time, site and stress level. Throughout, coated nylon fabrics were thicker, heavier and less flexible than coated cotton fabrics, the base fabrics being similar in mass per unit area. Fabrics coated with polyurethane or chlorosulphonated polyethylene tended to be thicker than those with natural or neoprene rubbers, whilst chlorosulphonated polyethylene coated fabrics were the heaviest. Polyurethane stiffened more than the other rubbers on storage or exposure, particularly when used on nylon. Load level had little effect on flexibility.

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